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Quarkonium shadowing in pPb and Pb+Pb collisions

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1. Quarkonium shadowing in $p\text{Pb}$ and $\text{Pb}+\text{Pb}$ collisions

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The d+Au data from RHIC, including the pA results from the fixed-target CERN SPS pA data, suggest increased importance of initial-state shadowing and decreasing nuclear absorption with increasing energy [1]. This is not surprising since smaller x is probed at higher energy while absorption due to multiple scattering is predicted to decrease with energy [2]. The CERN SPS data suggest a J/ψ absorption cross section of about 4 mb without shadowing, and a larger absorption cross section if it is included since the SPS x range is in the antishadowing region. The d+Au RHIC data support smaller absorption, $\sigma_{\text{abs}}^{J/\psi} \sim 0 - 2$ mb. Thus our predictions for J/ψ and Υ production in $p\text{Pb}$ and $\text{Pb}+\text{Pb}$ interactions at the LHC are shown for initial-state shadowing alone with no absorption or dense matter effects. We note that including absorption would only move the calculated ratios down in proportion to the absorption survival probability since, at LHC energies, any rapidity dependence of absorption is at very large $|y|$ [3], outside the detector acceptance.

We present $R_{p\text{Pb}}(y) = p\text{Pb}/pp$ and $R_{\text{PbPb}}(y) = \text{PbPb}/pp$ for J/ψ and Υ . Since the pp , $p\text{Pb}$ and $\text{Pb}+\text{Pb}$ data are likely to be taken at different energies (14 TeV, 8.8 TeV and 5.5 TeV respectively), to make the calculations as realistic as possible, we show several different scenarios for $R_{p\text{Pb}}(y)$ and $R_{\text{PbPb}}(y)$. The lead nucleus is assumed to come from the right in $p+\text{Pb}$. All the pA calculations employ the EKS98 shadowing parameterization [4]. The difference in the J/ψ and Υ results is primarily due to the larger Υ mass which increases the x values by about a factor of three. In addition, the higher Q^2 reduces the overall shadowing effect.

The top of Fig. 1 shows $R_{p\text{Pb}}(y)$ for $p\text{Pb}/pp$ with both systems at $\sqrt{s_{NN}} = 8.8$ and 5.5 TeV (dashed and dot-dashed curves respectively), ignoring the $\Delta y = 0.46$ rapidity shift at 8.8 TeV. For the J/ψ , these ratios are relatively flat at forward rapidity where the x in the lead is small. The larger x and greater Q^2 for the Υ brings the onset of antishadowing closer to midrapidity, within the range of the ALICE dimuon spectrometer. At far backward rapidity, a rise due to the antishadowing region is seen. The lower energy moves the antishadowing peak to the right for both quarkonia states. We show $R_{p\text{Pb}}(y)$ with $p\text{Pb}$ at 8.8 TeV and pp at 14 TeV with $\Delta y = 0$ in the dotted curves. The effect on the J/ψ is an apparent lowering of the dashed curve. Since the Υ rapidity distribution is narrower at 8.8 TeV than at 14 TeV in the rapidity range shown here, the Υ curve turns over at large $|y|$. (This effect occurs at $|y| > 6$ for the J/ψ .) The solid curves show $R_{p\text{Pb}}(y)$ for 8.8 TeV $p\text{Pb}$ and 14 TeV pp with the rapidity shift. Both the J/ψ and Υ ratios are essentially constant for $y > -2.5$. Thus relying on ratios of pA to pp collisions at different energies to study shadowing (or other small x effects) may be difficult because the shadowing function is hard to unfold when accounting for the pA Δy as well as the difference in x . If d+Pb collisions were used, Δy would be significantly reduced [5].

The lower part of Fig. 1 shows $R_{\text{PbPb}}(y)$ for the J/ψ and Υ at 5.5 TeV for both systems. No additional dense matter effects such as $Q\bar{Q}$ coalescence or plasma screening are included. The EKS98 (dashed) and nDSg [6] (dot-dashed) shadowing parameterizations are compared. The results are very similar over the entire rapidity range. (Other shadowing parameterizations, which do not agree with the RHIC d+Au data, give different $R_{\text{PbPb}}(y)$.) There are antishadowing peaks at far forward and backward rapidity. As at RHIC, including shadowing on both nuclei lowers the overall ratio relative to $R_{p\text{Pb}}(y)$ as well as making $R_{\text{PbPb}}(y > 2)$ similar to or larger than

$R_{\text{PbPb}}(y=0)$ because, without any other effects, $R_{\text{PbPb}}(y) \sim R_{p\text{Pb}}(y)R_{p\text{Pb}}(-y)$ when all systems are compared at the same $\sqrt{S_{NN}}$. The solid curves show the ratios for Pb+Pb at 5.5 TeV relative to pp at 14 TeV with the EKS98 parameterization. The trends are similar but the magnitude is lower.

Since these calculations reflect what should be seen if nothing else occurs, $R_{\text{PbPb}}(y)$ is expected to differ significantly due to dense matter effects. If the initial J/ψ production is strongly suppressed by plasma screening, then the only observed J/ψ 's would be from $c\bar{c}$ coalescence [7] or B meson decays. It should be possible to experimentally distinguish secondary production from the primordial distributions by displaced vertex cuts. Secondary J/ψ production should have a narrower rapidity distribution and a lower average p_T . Both are indicated in central Au+Au collisions at $\sqrt{S_{NN}} = 200$ GeV at RHIC [8]. If J/ψ production in central collisions is dominated by secondary J/ψ 's, peripheral collisions should still reflect initial-state effects. Predictions of the centrality dependence of shadowing on J/ψ production at RHIC agree with the most peripheral Au+Au data.

Finally, the J/ψ and Υ rapidity distributions are likely to be inclusive, including feed down from higher quarkonium states. Initial-state effects should be the same for all members of a quarkonium family so that these ratios would be the same for direct and inclusive production.

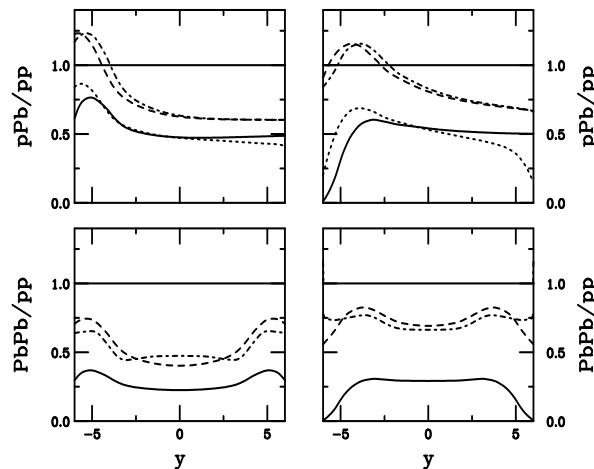


Figure 1. The J/ψ (left) and Υ (right) $p\text{Pb}/pp$ (top) and PbPb/pp (bottom) ratios as a function of rapidity. The $p\text{Pb}/pp$ ratios are given for 8.8 (dashed) and 5.5 (dot-dashed) TeV collisions in both cases and 8.8 TeV $p\text{Pb}$ to 14 TeV pp without (dotted) and with (solid) the beam rapidity shift taken into account. The PbPb/pp ratios are shown for 5.5 TeV in both cases with EKS98 (dashed) and nDSg (dot-dashed) shadowing and also for 5.5 TeV $\text{Pb}+\text{Pb}$ and 14 TeV pp (solid).

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